The Opportunity

- DWDM optical transport networks require wavelength-selective switching functions to provide network management for wavelength-based service provisioning, bandwidth management, optical-layer protection and restoration.

  – OADM, WSXC and protection switches

- No integrated all-optical solutions exist yet

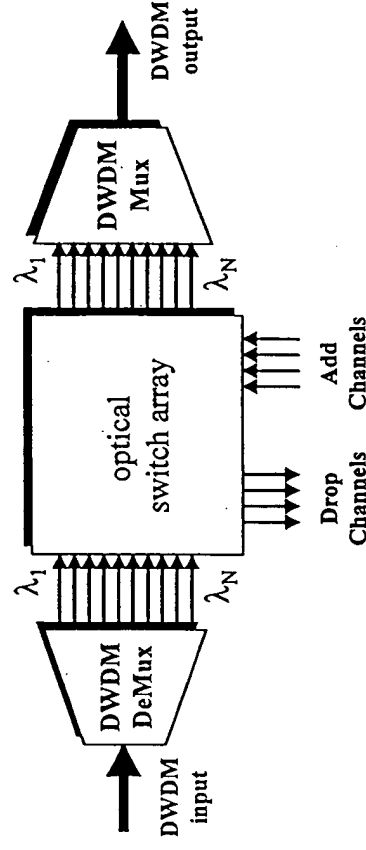- We can be the first to offer integrated all-optical dynamic wavelength routing

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Wavelength Router, also referred to as Wavelength Routing Element™ or WRE

OADM Conventional Solution

Cost = $3,000 per λ

COPY

Everybody Else's Solution

1. De-multiplex the DWDM stream into individual wavelengths on separate fibers

2. Switch the optical fibers electronically or optically (OXC, FXC)

3. Re-multiplex all the fibers into DWDM.

Complex and Expensive!

An Alternative Approach
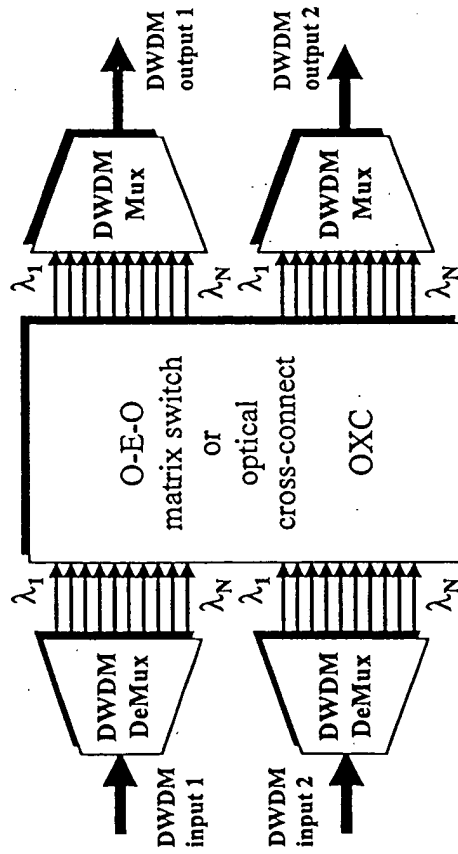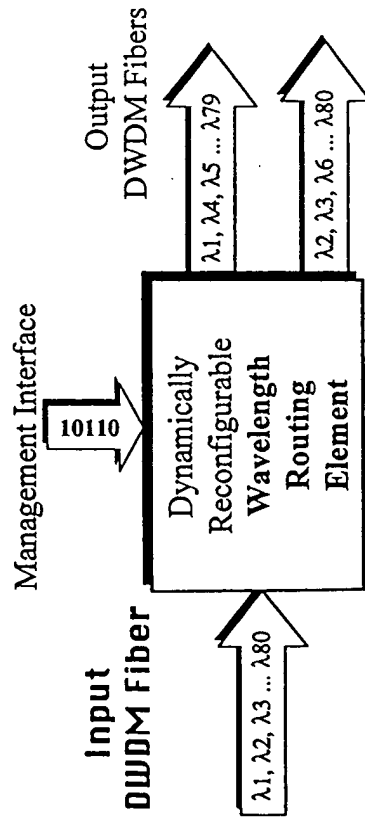
- Network Photonics has a novel solution:

Wavelength Routing Element™

All-optical wavelength routing component which enables networking functions by directly switching wavelengths instead of switching fibers.

WSXC Conventional Solution

DWDM input 1 → DWDM DeMux → λ_1 ... λ_N → O-E-O matrix switch or optical cross-connect OXC → λ_1 ... λ_N → DWDM Mux → DWDM output 1

DWDM input 2 → DWDM DeMux → λ_1 ... λ_N → λ_1 ... λ_N → DWDM Mux → DWDM output 2

Cost = \$3,000-\$5,000 per λ per fiber

Wavelength Routing Element™
it works in both directions

Management Interface 10110 → Dynamically Reconfigurable Wavelength Routing Element

Input DWDM Fibers: $\lambda1, \lambda4, \lambda5 ... \lambda79$; $\lambda2, \lambda3, \lambda6 ... \lambda80$

Output DWDM Fiber: $\lambda1, \lambda2, \lambda3 ... \lambda80$

Any wavelength from any input

Wavelength Routing Element™

Management Interface 10110 → Dynamically Reconfigurable Wavelength Routing Element

Input DWDM Fiber: $\lambda1, \lambda2, \lambda3 ... \lambda80$

Output DWDM Fibers: $\lambda1, \lambda4, \lambda5 ... \lambda79$; $\lambda2, \lambda3, \lambda6 ... \lambda80$
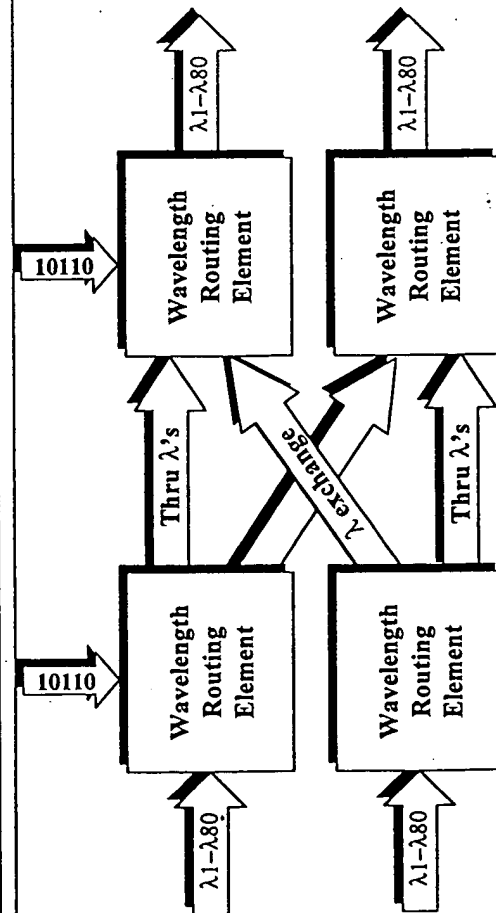
Any wavelength to any output

A Building Block

- The WRE is a building block for many optical layer applications:
  - Optical Add-Drop Multiplexer
  - Wavelength-Selective Cross-connect
  - Wavelength-Selective Protection Switching
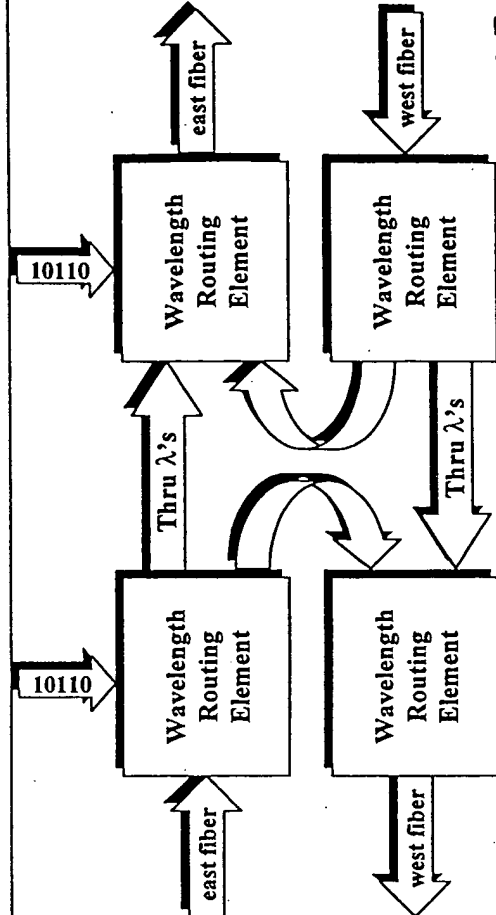 - Wavelength Distribution Router

WRE Configurations: Optical Add/Drop Multiplexer (OADM)

$\lambda 1-\lambda 80$ · 10110 · Wavelength Routing Element · Thru λ's · Drop · Add · Drop λ's · Add λ's

Cost = $700 per λ

WRE Configurations: Wavelength-Selective Cross-Connect

$\lambda 1-\lambda 80$ · 10110 · Wavelength Routing Element · Thru λ's · λ exchange

WRE Configurations: BLSR Protection Switching

east fiber · west fiber · 10110 · Wavelength Routing Element · Thru λ's · east fiber · west fiber

COPY

WRE Technology Overview

- 2 parts working in combination:
  - Dispersion-Free Spectrometer (DFS)
  - Micro-optic Routing Array (MRA)
- DFS performs spatial conversion of multiplexed wavelengths
- MRA performs switching/routing functions

DFS Overview

- DFS is the heart of the WRE
  - a single design for dynamic and passive WREs
- Requires only one optical element both for wavelength separation and recombination
- Based on free-space diffractive optics
  - unique light path eliminates chromatic dispersion
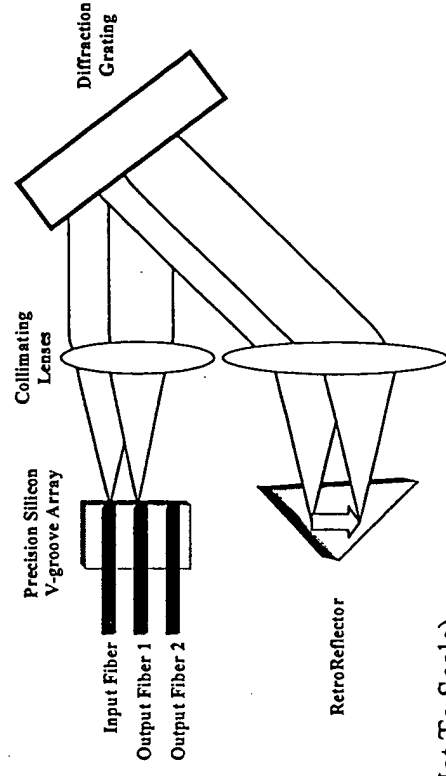- no electronics or moving parts

MRA Overview

- Implemented as an array of micro-optic retroreflectors
- Performs either dynamic or static routing
  - dynamic design uses electronic actuation
  - static design requires no power
- Non-blocking and latching

DFS Light Path

Diffraction Grating; Collimating Lenses; Precision Silicon V-groove Array; Input Fiber; Output Fiber 1; Output Fiber 2; RetroReflector

(Not To Scale)

MEMS Tilting MicroMirror Design

±10°
Tilting
Mirror

Fixed
Mirrors

50 μm

Mirror array on
silicon substrate

Quartz-mount

Directly Switching Wavelengths

RetroReflector Array
Front View

Imaged Spectral
Plane

Tilting
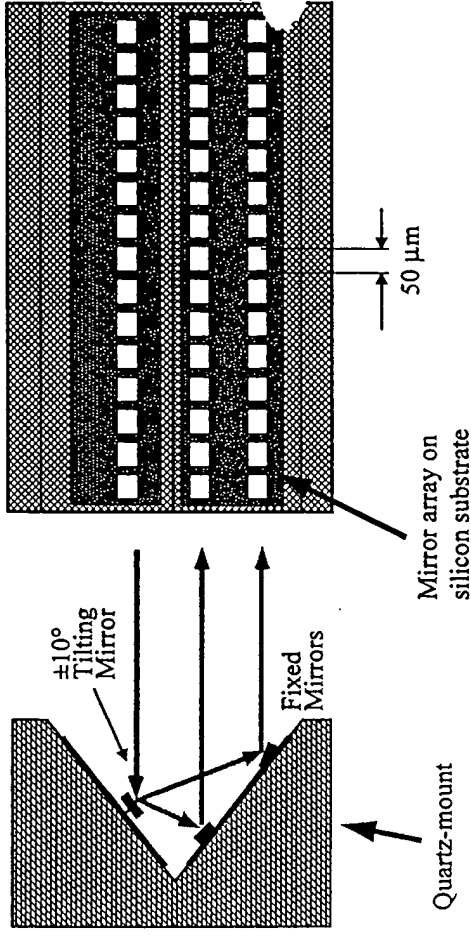Mirrors

Upper
Reflection
Mirrors

Lower
Reflection
Mirrors

Dynamic MRA Implementation

• MEMS tilting micromirror array

- proprietary design

- one switching mirror per λ fabricated on a
  5 mm x 50 mm silicon substrate

- requires only ± 10° mirror tilt

  ◆ can use Texas Instruments DMD technology

  ◆ CMOS semiconductor fab process

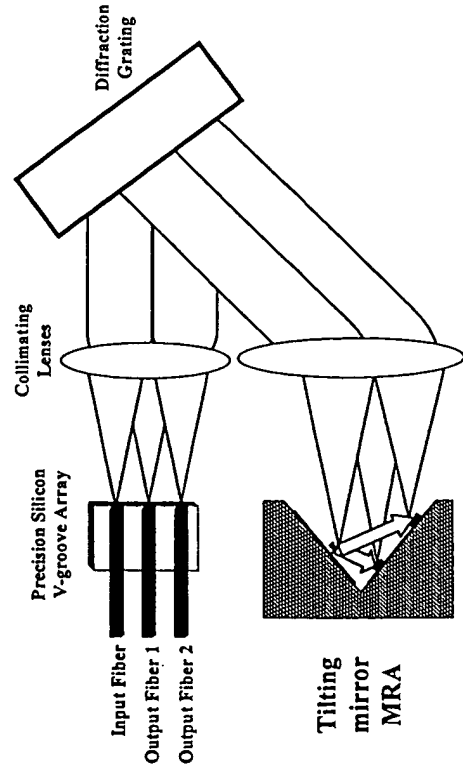# WRE Switching

Diffraction
Grating

Collimating
Lenses

Precision Silicon
V-groove Array

Input Fiber
Output Fiber 1
Output Fiber 2

Tilting
mirror
MRA

Dynamic WRE

- Dynamically-reconfigurable routing
- 250 μsec switching time
- Latching
  - retains configuration with power off
- Scales to higher or lower DWDM channel densities

Trapezoidal Passbands
Superior Optical Performance

- 50 GHz channel spacing
- uniform gain characteristic across all channels
- low insertion loss - 3dB
- low crosstalk and high SNR - 40dB

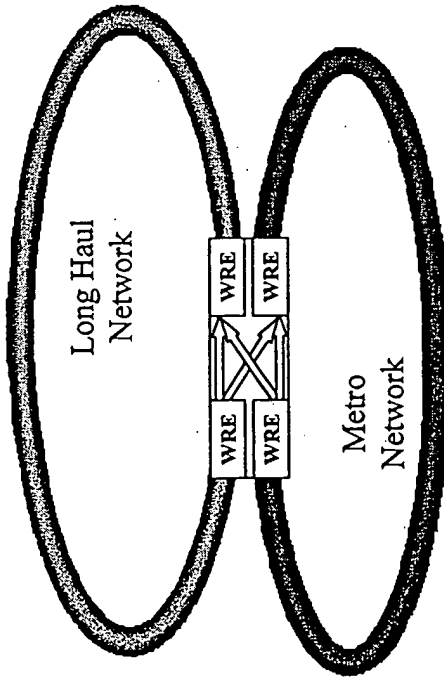## WRE Value Proposition

- Integrated subsystem functionality
  - simpler system design
    - no need to de-mux & re-mux
    - far fewer switching elements
    - far fewer fiber connections
- Lower system cost
  - less than _ the cost of alternatives
- Superior optical performance
- Higher system reliability

Passive WRE

- Static MRA is fabricated on a silicon chip using gray-scale photolithography
  - no electronics or moving parts
  - proprietary design for 3-D retroreflector array
  - low-cost volume-fabrication process
  - same DFS as DWRE

Network Applications:
Network Interconnect

Long Haul Network

Metro Network

Network Applications:
Undersea Passive OADM

Mediterranean undersea fiber optic network

OADM

1st set of λ's to/from Cairo

2nd set of λ's to/from Tel Aviv

3rd set of λ's to/from Beirut

Network Applications:
2-f BLSR Restoration

BLSR Restoration Switch

East fiber

West fiber

East fiber

West fiber

Network Applications:
FTTx Distribution Router

FTTx Router

DWDM input fiber

Tributary output fibers

Document comparison done by DeltaView on Monday, December 08, 2003 2:32:12 PM

Input:	
Document 1	file://H:/PTS/19930-1.DOC
Document 2	file://H:/PTS/19930-1-3 Sub Spec for Div.DOC
Rendering set	Standard

Legend:	
Insertion	
~~Deletion~~	
~~Moved from~~	
Moved to	
Style change	
Format change	
~~Moved deletion~~	
Inserted cell	
Deleted cell	
Moved cell	
Split/Merged cell	
Padding cell	

Statistics:	
	Count
Insertions	140
Deletions	43
Moved from	1
Moved to	1
Style change	0
Format changed	0
Total changes	185